ARR No. E5E04a

E-43

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED

June 1945 as
Advance Restricted Report E5E04a

THE EFFECTS OF AN INCREASE IN THE CONCENTRATION OF ETHYLENE DIBROMIDE IN A LEADED FUEL ON LEAD DEPOSITION, CORROSION OF EXHAUST VALVES, AND KNOCK-LIMITED POWER

By B. A. Mulcahy and M. A. Zipkin

Aircraft Engine Research Laboratory
Cleveland, Ohio

NACA

WASHINGTON

E-43

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

THE EFFECTS OF AN INCREASE IN THE CONCENTRATION OF ETHYLENE DIBROMIDE IN A LEADED FUEL ON LEAD DEPOSITION, CORROSION OF EXHAUST VALVES, AND KNOCK-LIMITED POWER

By B. A. Mulcahy and M. A. Zipkin

INTRODUCTION

Hot corrosion of the crown of the exhaust valve has been found to be one of the principal causes of exhaust-valve failures (reference 1). Banks (reference 2) and Hives and Smith (reference 3) have concluded that this hot corrosion is a result of the action of lead oxide deposited on the head of the valve during the combustion of a fuel containing tetraethyl lead. Analysis of deposits on the crowns of several exhaust valves has shown a large percentage of the deposit to be lead compounds, which indicates that all of the lead was not scavenged from the cylinder.

In order to prevent the formation of these lead deposits within the cylinder, ethylene dibromide is added to the leaded fuel. The function of the ethylene dibromide is to react with the lead to form volatile compounds that will be scavenged with the exhaust gases. Fuels currently used in aircraft engines contain 0.96 gram of ethylene dibromide per milliliter of tetraethyl lead, which is the quantity theoretically required to combine with the lead. A fuel containing this concentration of ethylene dibromide is designated a 1-T mix.

In order to determine whether an excess of ethylene dibromide might decrease the amount of unscavenged lead in the cylinder and thereby reduce valve-crown corrosion, two engine tests (tests A and B) were conducted during June and July 1944 at the NACA Cleveland laboratory using a 1-T mix and a 2-T mix (a fuel containing twice the amount of ethylene dibromide theoretically required to combine with the lead) and the amounts of resulting valve corrosion were compared. A third test (test C) was run to investigate the possibility that additional ethylene dibromide in the fuel might, by combining with the lead, reduce the knock-limited power obtainable

with the fuel. Knock-limited indicated mean effective pressure in a Wright C9GC cylinder was determined over a range of fuel-air ratios for 1-T and 2-T mixes of AN-F-28 (28-R) fuel.

APPARATUS AND TEST PROCEDURE

In all the tests standard laboratory equipment was used to measure engine speed, power output, cylinder temperatures, and fuel and air consumption. Knock was detected by a magnetic-type knock-indicator pickup mounted on the rear spark plug and connected to a cathode-ray oscilloscope.

Test A, which consisted of two runs, was conducted on an NACA universal test engine crankcase with a used Wright C9GC cylinder. An unused Wright C9GC exhaust valve was employed for each run. The first run of test A consisted of 22 hours of operation using a 1-T mix of AN-F-28 (28-R) fuel, containing 4.53 milliliters of tetraethyl lead per gallon. The second run using an additional 4.35 grams of ethylene dibromide per gallon (2-T mix) was terminated after $16\frac{1}{2}$ hours' operation because of excessive afterfiring. Afterfiring was noted throughout both runs, but on the second run the afterfiring reached the point at which the operator deemed it advisable to shut down.

After each run the deposit on the crown of the piston was removed and analyzed for lead content. The deposits on the valve crowns resulting from combustion were removed by the electrolytic process described in reference 4. The amount of corrosion was determined on the basis of weight loss sustained by each valve during operation at the following conditions:

Engine speed, rpm	2200
Fuel-air ratio	0.081
Indicated mean effective pressure, pounds per square inch . . .	205
Temperature of rear spark-plug bushing, °F	450
Combustion-air inlet temperature, °F	150
Spark advance, degrees B.T.C.	22.5

Tests B and C were run on a single-cylinder conversion of a Wright R-1820-73 crankcase with a used Wright C9GC cylinder. In test B comparative weight-loss runs were made on two unused valves using 1-T and 2-T mixes of AN-F-28 (28-R) fuel with the tetraethyl lead content increased to 6.0 milliliters per gallon. The test consisted of 18 hours of engine operation with each valve at the same engine conditions as those of test A with the exception of the combustion-air inlet temperature, which varied between 90° F and 100° F. No combustion-air heater was available for this test.

In test C knock-limited indicated mean effective pressure was determined over a range of fuel-air ratios for 1-T and 2-T mixes of AN-F-28 (28-R) fuel under the following conditions:

Engine speed, rpm 2200
Combustion-air inlet temperature, °F 250
Spark advance, degrees B.T.C. 20
Cooling-air pressure drop across cylinder, inches of water . . 8

RESULTS AND DISCUSSION

The results of tests A and B to determine the effect of ethylene-dibromide concentration on lead corrosion of the exhaust valve are summarized in the following table:

Fuel		Length of test (hr)	Weight loss of valve		
TEL (ml/gal)	Mix		Total (grams)	Rate (gram per hour)	Rate (percentage of loss with 1-T mix)
4.53	1-T	22	5.18	0.235	100
	2-T	$16\frac{1}{2}$	1.97	.119	51
6.0	1-T	18	3.17	0.176	100
	2-T	18	.53	.029	16

The exhaust valves used in test A are shown in figure 1 before they were cleaned. The valve tested in the first run with the 1-T mix shows considerable deposit (fig. 1(a)), whereas the other valve operated in the second run with the 2-T mix shows less deposit (fig. 1(b)). The same trend was observed after 18 hours' operation with the lead content of the fuel increased from 4.53 to 6.0 milliliters per gallon. (See fig. 2.)

After both runs of test A, the deposit on the piston crown was removed and analyzed to determine the lead content. The piston crown was used instead of the valve crown to determine the amount of deposit because of its larger area and because the corrosion of the valve makes quantitative analysis of deposits difficult. It was found that the rate of lead deposit on the piston crown during the portion of the test using 2-T mix was 73 percent of the rate during the portion using 1-T mix.

In test B when the lead content of the fuel was increased to 6 milliliters per gallon, measurements were made of the amount of material deposited on the spark-plug electrodes. These data are presented in the following table:

Spark plug	Mix	Weight of deposit (gram)	Reduction in deposit (percent)
Front	1-T	0.083	0
	2-T	.021	75
Rear	1-T	0.109	0
	2-T	.014	87

The conditions selected for test A were such that the exhaust-valve temperature would be approximately 1200° F as estimated from the data of figure 6 of reference 5. In test B the combustion-air inlet temperature was reduced from 150° F to 95° F ±5° F, which resulted in a reduction in valve temperature. This change in valve temperature probably accounts for the reduction in amount of valve corrosion in test B.

The results of test C are presented in figure 3, which shows knock-limited indicated mean effective pressures obtainable in a Wright C9GC cylinder with 1-T and with 2-T concentrations of ethylene dibromide in the fuel. When the ethylene-dibromide concentration was increased to a 2-T mix, there was apparently no effect on knock limit over the range of conditions investigated; all test points with both fuels fell on a single curve within the limits of reproducibility. The knock tests were conducted without disassembly of the engine and no attempt was made to measure valve corrosion during these tests.

The increase in knock-limited power obtainable by increasing the amount of tetraethyl lead in S reference fuel is shown in figure 4, which was plotted from unpublished data. Increase of the lead content of fuels is limited principally by the resulting lead deposits on the spark-plug electrodes and by the lead corrosion of the exhaust valve. Inasmuch as these effects are reduced by the use of additional ethylene dibromide, advantage could be taken of the higher power obtainable with increased tetraethyl-lead content if the proportion of ethylene dibromide to tetraethyl lead were increased.

SUMMARY OF RESULTS

The following results were obtained from tests run to determine whether an excess of ethylene dibromide might decrease the amount of unscavenged lead in the cylinder and thereby reduce valve-crown corrosion:

1. When ethylene dibromide in excess of the amount theoretically required to combine with the lead in the fuel (1-T mix) was added, the corrosion of the exhaust-valve crown and the material deposits on the piston and spark plugs were reduced.

2. Fuel containing twice the theoretical amount of ethylene dibromide (2-T mix) produced the same knock-limited indicated mean effective pressure as did fuel containing the theoretical amount of ethylene dibromide (1-T mix).

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

REFERENCES

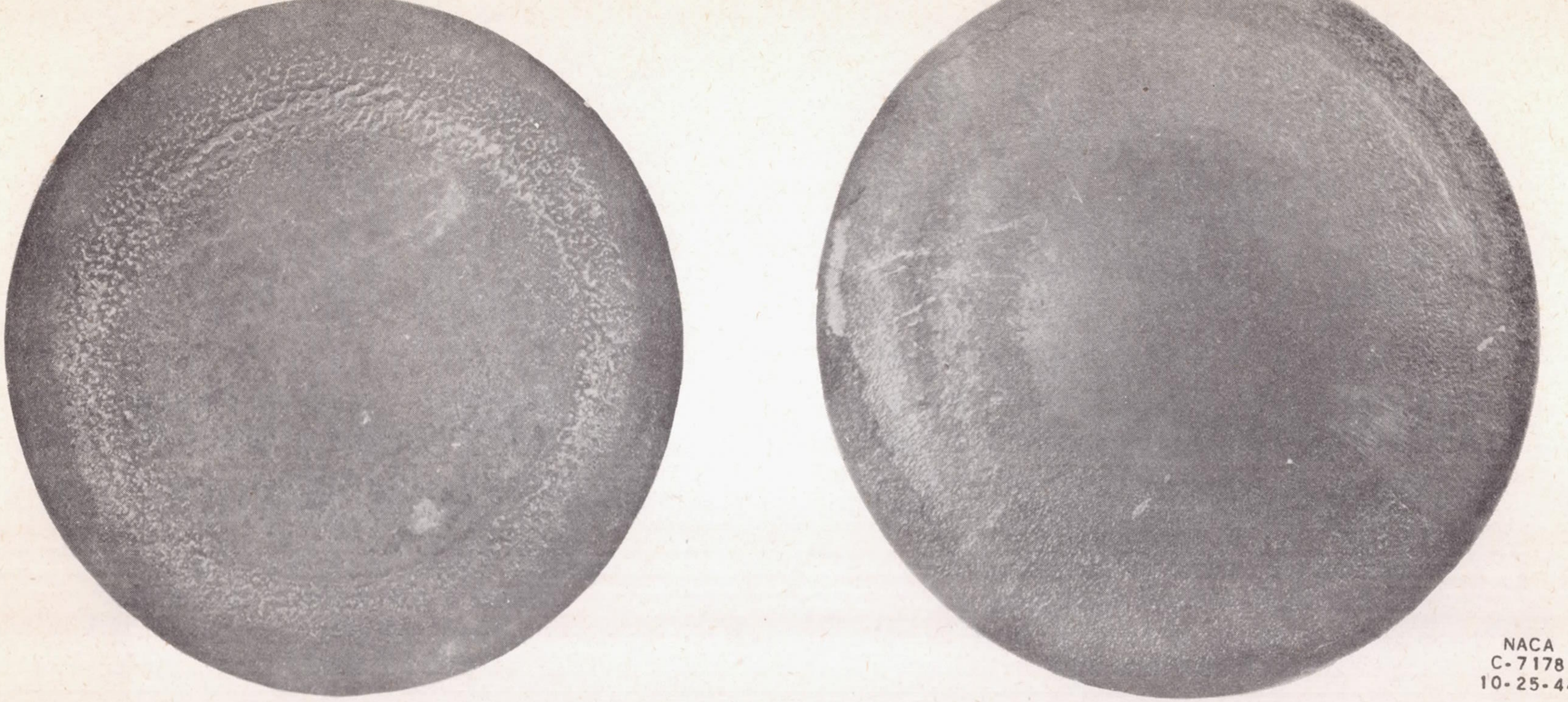
1. Sanders, J. C., Mulcahy, B. A., and Peters, M. D.: Some Factors Affecting Failures of Exhaust Valves in an Air-Cooled Cylinder. NACA ARR No. 4A19, 1944.

2. Banks, F. R.: Some Problems of Modern High-Duty Aero Engines and Their Fuels. Jour. Inst. Petroleum Technologists, vol. 23, no. 160, Feb. 1937, pp. 63-137; discussion, pp. 138-177.

3. Hives, E. W., and Smith, F. Ll.: High-Output Aircraft Engines. SAE Jour. (Trans.), vol. 46, no. 3, March 1940, pp. 106-117.

4. Heron, S. D., Calingaert, George, and Dykstra, F. J.: The Electrolytic Cleaning of Exhaust Valves. SAE Jour., vol. 37, no. 6, Dec. 1935, pp. 19-21.

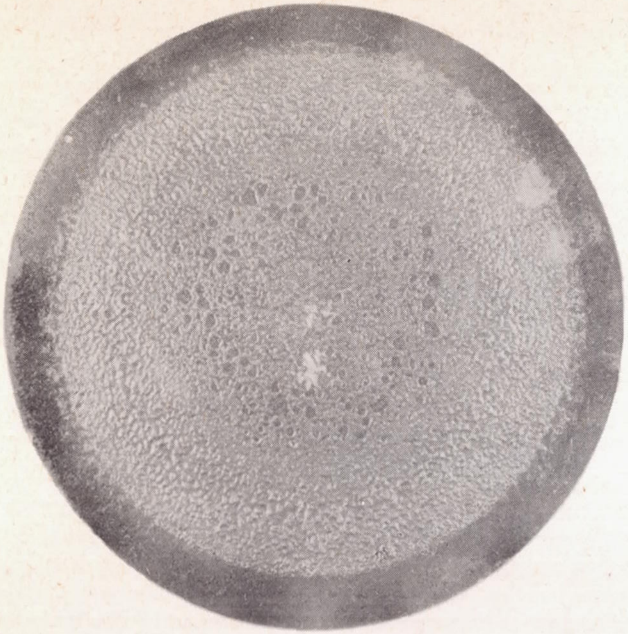
5. Mulcahy, B. A., and Zipkin, M. A.: Operating Characteristics of a Standard Wright C9GC Exhaust Valve and an Exhaust Valve with a Stem of Increased Diameter and a Crown with a Corrosion-Resistant Coating. NACA ARR No. E4I18, 1944.

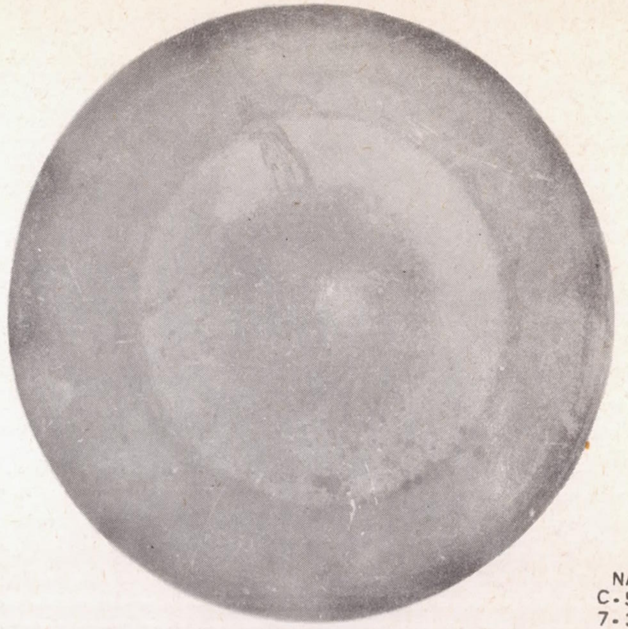


(a) Valve after 22 hours of operation using 1-T mix.

(b) Valve after $16\frac{1}{2}$ hours of operation using 2-T mix.

Figure 1. - Comparison of exhaust valves after operation with fuels having different concentrations of ethylene dibromide. Wright C9GC cylinder; engine speed, 2200 rpm; indicated mean effective pressure, 205 pounds per square inch; fuel-air ratio, 0.081; fuel, AN-F-28 (28-R) with 4.53 milliliters of TEL per gallon.





(a) Valve after test using 1-T mix.

(b) Valve after test using 2-T mix.

Figure 2. - Comparison of exhaust valves after 18 hours of engine operation with fuels having different concentrations of ethylene dibromide. Wright C9GC cylinder; engine speed, 2200 rpm; indicated mean effective pressure, 205 pounds per square inch; fuel-air ratio, 0.081; fuel, AN-F-28 (28-R) with 6.0 milliliters of TEL per gallon.

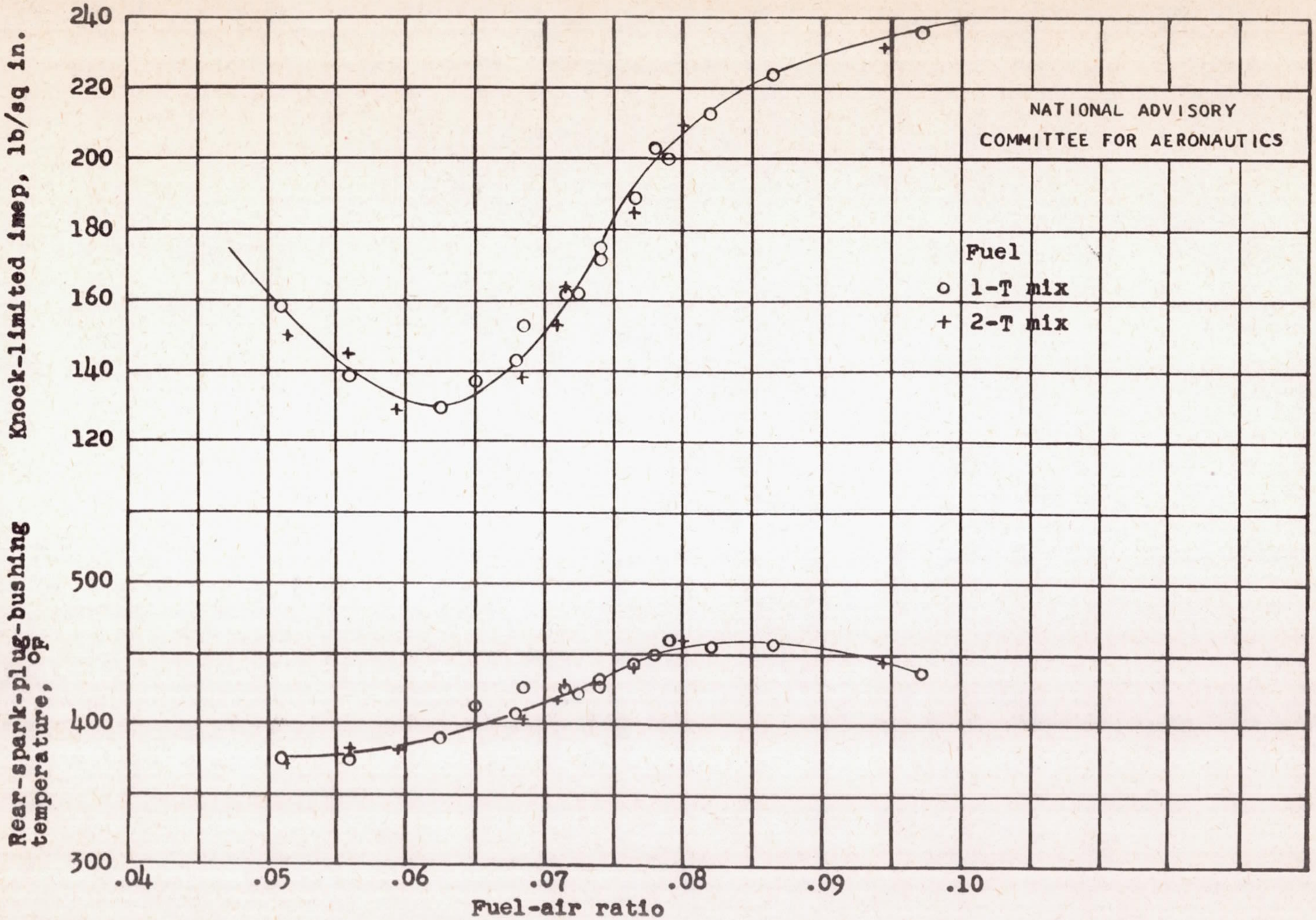


Figure 3. - Comparison of knock-limited indicated mean effective pressure of fuels with different concentrations of ethylene dibromide. Wright C9GC cylinder; engine speed, 2200 rpm; combustion-air temperature, 250° F; cooling-air pressure drop across cylinder, 8 inches of water; spark timing, 20° B.T.C.

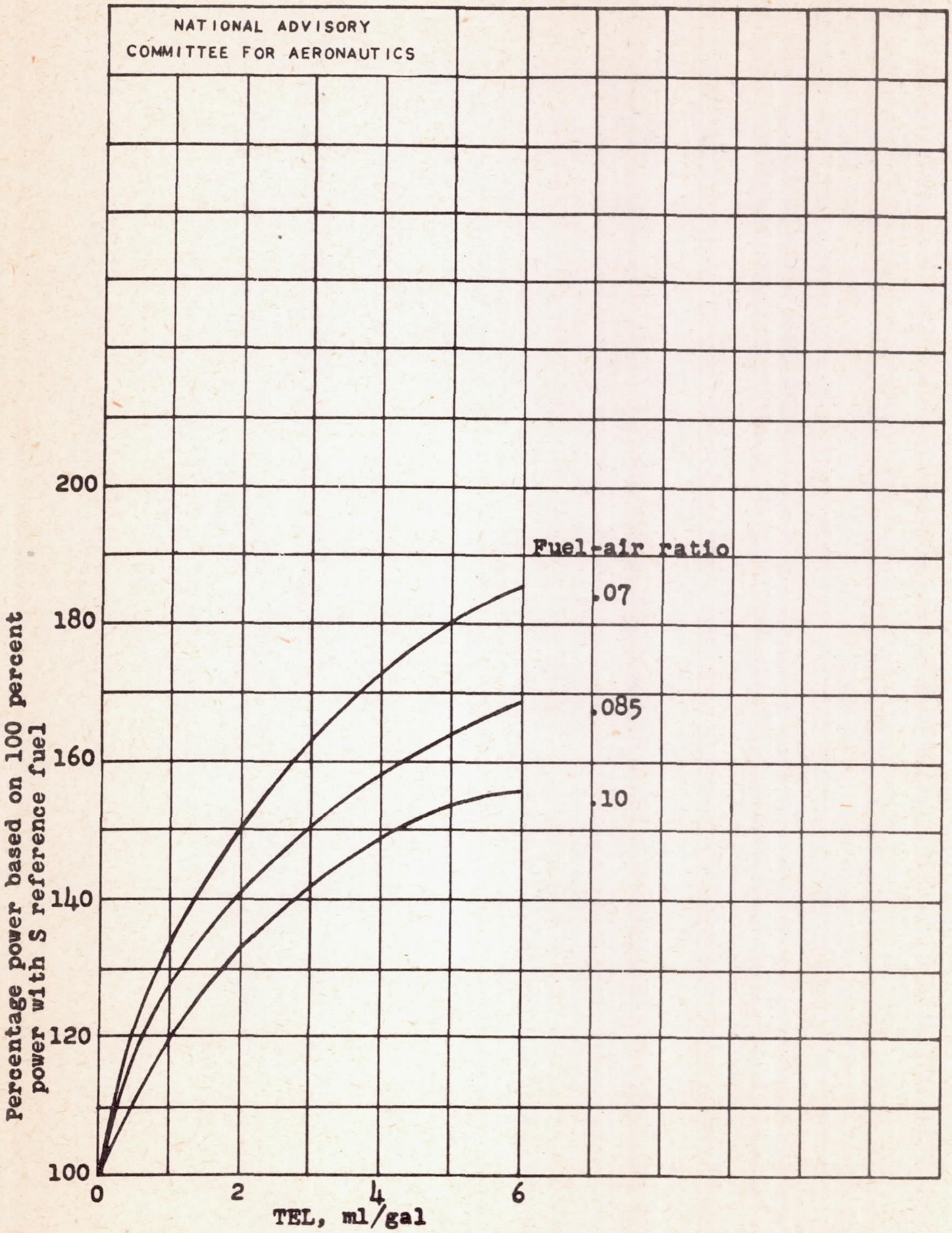


Figure 4. - Variation of power increase with tetraethyl-lead concentration for S reference fuel as determined by the F-4 rating method. (Plotted from unpublished data.)